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By-Smith, Robert L.; Seagraves, Charles, III

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The study was conducted (1) to survey and evaluate the current use of computers in the Texas System of Higher Education, (2) to study the role of computers in the institutions of the system for the immediate future (1967-1970), and (3) to project the role of computers at the institutions for the foreseeable future (1971-1980). A list of 17 findings and recommendations are presented. Some findings indicate that computers are used in a few state-supported colleges and universities in Texas to register students, produce payrolls, and keep track of the various inventories that must be maintained. There is a shortage of specialists educated in the computer sciences at both graduate and undergraduate levels, and computer-oriented research programs are almost nonexistent. It is felt that all college and university students should acquire some basic understanding of computers on their campuses, and students majoring in business, engineering, and science should be trained to use computers as tools of their trades, since their future careers will require this knowledge. Computer science departments should be established at selected 4-year institutions, and doctoral programs should be developed. The report also contains a discussion on future trends in computing, and compares computer developments in Texas with those in other states. (WM)

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U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION

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A Study of
THE ROLE AND SCOPE OF COMPUTERS
in the
TEXAS SYSTEM OF HIGHER EDUCATION

ROBERT L. SMITH and CHARLES SEAGRAVES, III

COORDINATING BOARD

TEXAS COLLEGE AND UNIVERSITY SYSTEM

May, 1968

Foreword

With its Study Paper Series, the Coordinating Board staff is making available to the Texas academic community and other interested citizens results of education research projects undertaken by or for the Board.

Our hope is that readers of these Study Papers will find them of value; and that comments and criticisms will be sent to us. We invite reactions to these studies, and especially to any recommendations made therein. We invite, as well, suggestions for future research on Texas post-high school education which you believe should be undertaken.

Comments and requests for additional copies of this Paper should be addressed to the Coordinating Board Offices, Sam Houston State Office Building, 201 East 14th Street, Austin, Texas 78701.

J. K. Williams
Commissioner of Higher Education

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PREFACE

A study group that is charged with responsibility for formulating recommendations to be implemented on a state-wide basis must necessarily avoid the danger of presenting a biased case either intentionally or unintentionally. In our attempt to present as objective a report as possible, the assistance of several of the more active computer specialist and educators in the Texas System of Higher Education was obtained. We would like to take this opportunity to express our appreciation to these individuals for their time, effort, and splendid cooperation throughout the survey. They are:

DR. ROBERT T. GREGORY, *Professor*
The University of Texas at Austin

MR. G. W. HARDIN, *Director EDPC*
Stephen F. Austin State College

MR. FRED H. HARRIS, *Asst. Director, Research Computation Lab*
Rice University

MR. RICHARD HARRIS, *Director of Computer Systems*
North Texas State University

MR. JIM HILL, *Director of Data Processing Services*
Dallas County Junior College District

MR. JIMMIE C. STYLES, *Vice President for Program Development*
Tarrant County Junior College District

MR. J. B. WYATT, *Director, University Computing Center*
University of Houston

The professional members of the survey staff were:

Principal Investigator: MR. ROBERT L. SMITH, JR., *Director,* Data Processing Center, Texas A&M University

Principal Investigator: MR. CHARLES SEAGRAVES, III, *Systems Analyst,* Texas A&M University

Assistant Investigator: MR. ROBERT BOWER, JR., *Acting Head,* Data Processing Center, Texas A&M University

Assistant Investigator: MR. PAUL M. BRIGGS, *Systems Analyst,* Texas A&M University

Assistant Investigator: MR. BRUCE W. STEWART, *Systems Analyst,* Texas A&M University

Professor Robert L. Smith, Jr., who was the principal investigator of this study at its initiation, left Texas A&M on September 1, 1967. He has continued to work closely with the survey staff and is to be commended for his personal efforts to improve computing in Texas Higher Education.

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INTRODUCTION, FINDINGS, AND RECOMMENDATIONS

Very few, if any, developments will have more effect on mankind than the development of the electronic computer. In slightly more than two decades, the computer has had a profound effect on the ever-changing world, and their effect during the next two decades will most likely be even more profound. Dr. John R. Pierce of Bell Laboratories defined the present state of computer technology when he said: "After growing wildly for years, the field of computing now appears to be approaching its infancy." The invasion of computers into all areas of technology, allowing people to solve problems here-to-fore thought to be unsolvable, has placed a tremendous challenge before the colleges and universities of this nation. The social and economic gains made possible by computers and computing appear to be limited only by the availability of people who are able to apply these tools in new and useful ways. It is the responsibility of the colleges and universities to insure that their graduates are prepared to meet today's technological challenges and that they are adaptable to change to meet tomorrow's challenges. This is a big responsibility. Unfortunately, many colleges and universities, because of lack of understanding or lack of resources, are not accepting this responsibility.

The purpose of this study was threefold. First, the present use of computers in the Texas System of Higher Education was to be surveyed and evaluated. Second, the role of computers in these institutions for the immediate future (1967–70) was to be studied, and third, a projection for the foreseeable future (1971–80) of the role of computers at these institutions was to be made. Furthermore, computer developments in Texas was compared with those in other states.

This report contains seven sections. This section summarizes the recommendations and findings of the study. The second section presents an overview of computing in Texas higher education. The third, fourth, and fifth sections are primarily concerned with computers in teaching, research, and administration. Section six is a comparison of computing in Texas higher education to computing nationally. The final section concerns future trends in computing.

The major findings and recommendations of the study are:

1. Computers are presently used in many of the state-supported institutions of higher learning in Texas. In the vast majority of the institutions, however, students have relatively little or no opportunity to learn about the computer or use its capability. In many disciplines some exposure to computers and their capabilities is essential to attain a working knowledge of the field.
   It is recommended that suitable computing facilities be available to all institutions of higher learning to prepare adequately students in all disciplines.

2. The primary constraint on computer usage in most state-supported institutions of higher learning is the shortage of funds. Computers are expensive. Even with significant reductions in price allowed by some manufacturers in the form of educational discounts, many schools are simply unable to afford the computing capability they need because of budgetary limitations. In many instances, computers are considered a luxury, rather than a required facility, such as libraries or chemistry laboratories.
   It is recommended that a formula system for state funding of computer costs be established for educational and general computer activities in state-supported institutions of higher education.

3. Centralized computer facilities are now more common than decentralized facilities in the state-supported educational institutions in Texas. This centralization of computing facilities presents a great opportunity for economy—but a challenge to effective management.
   Nevertheless, centralization of computing facilities is a desirable environment, both academically and administratively, provided that accessibility for the student and researcher can be guaranteed.
   It is recommended that centralization of computer facilities be encouraged in state-supported institutions of higher learning in Texas, where an adequate level of service can be provided for all users.

4. Use of the "computer network" approach appears to offer an efficient way to provide adequate computing capability to all institutions of higher learning. As a part of a network, smaller institutions would use their small-to medium- scale computers to process the majority of their work. Those jobs

that could not be adequately handled by the local computer systems would be processed at larger installations. Ultimately, every institution of higher learning would be a part of some computer network. It is expected that several regional networks would be required, with many smaller colleges being connected to the regional center via telephone lines or microwave. For the immediate future, the use of common carriers to transport magnetic tapes between schools could provide one day service and might serve as a temporary measure until a computer network could be implemented.
It is recommended that the establishment of regional computer networks be encouraged through direct supplemental funding at the state level.

5. In order to obtain the maximum utilization and benefit of a computer, the computer center should be established as a service facility, furnishing computing services for all institutional users under a realistic budget structure. The computer should be considered as an institutional resource and should therefore be under the direct control of an administrator so placed as to be cognizant of the needs of the institution.
It is recommended that a policy of having a centralized computer facility under the control of a ranking administrator be encouraged at all state supported institutions of higher education.

6. With the impact and advancement of computer techniques on all disciplines, it is imperative that computer science programs be established in the institutions of higher learning in Texas. Some of the requirements which must be met by these instructional programs include: computer science faculty development, advanced levels of research in computer science, education of computer scientists for industry, training of computer technicians, and educational programs in the impact and use of computers in all disciplines. *It is recommended* that four distinct levels of instruction in computing should be made available to students in state supported colleges and universities, including both undergraduate and graduate levels: (1) undergraduate and graduate programs in computer science which will further the development of computer faculties and foster advanced development in computing, (2) training of computer technicians to meet growing industry needs, (3) education of students in key disciplines who have a need to use the computer as an essential tool, and (4) providing to all students an understanding of the impact of computers on society.

7. All students should acquire some understanding of computing in our modern society. Computing will soon take its place as a fundamental area of knowledge with government, history, arithmetic, etc. The establishment of effective programs to meet this basic need will require that every state supported institution of higher learning assign some department primary responsibility for general instruction in computing.
It is recommended that an appropriate department in each state supported institution be given the responsibility for general education in computing at given levels of instruction, for students in all disciplines.

8. The institutions of higher learning in Texas have been primarily concerned with the education of personnel to fill positions in the higher levels of data processing and computing. There is, however, a critical shortage of technicians in computing and very little is being done to alleviate the situation. This gap in educational coverage could be handled by the junior colleges of the state. For example, a junior college might have as one of its objectives a program to train a two-year technical programmer, while a college or university would educate the systems analysts and other higher level personnel.
It is recommended that the junior colleges be given the responsibility for training computer technicians, such as computer operators and technical programmers, in the state.

9. There is a growing need for specialists educated in the computer sciences at both the graduate and undergraduate levels. This education can be provided only in an environment which offers both a good faculty and access to good computing facilities for both course work and research. It is imperative that departments of computer science be established at those larger institutions which have adequate computing resources to support an advanced instructional program.
It is recommended that Computer Science Departments be established in selected four-year institutions.

10. There is a critical shortage of instructional programs to educate computer scientists at the doctoral level. The computer scientist educated today will be expected to provide impetus for the future development of computers and computing, as well as to serve in faculty positions and assist in expanding computer science programs.

It is recommended that selected major institutions in the state be given the responsibility for developing doctoral programs to educate computer scientists.

11. The whole success of educational computing and continued improvement in its use depends on expanded education and research in computer sciences. The graduate programs and associated computing facilities of universities are ideal environments in which this type of research can flourish.
It is recommended that research programs in the field of computer science be established and funded in appropriate state supported colleges and universities in Texas.

12. In considering the cost of computing in support of educational activities, the allocation of funds often presents a problem. Treatment of funds intended for non-sponsored research as a reduction in total cost reduces the hourly charge for computer time paid by all users and has the effect of shifting research costs to educational users.
It is recommended that each institution be allocated separate funds specifically for computer usage in support of non-sponsored research.

13. Colleges and universities today are increasing both in size and complexity. As this trend continues, greater effort is required to maintain the operation of these institutions. This requirement is partially satisfied by an increase in personnel with a corresponding rise in cost. In many instances, however, not enough qualified people are available to fill the number of positions required and the result is a loss of efficiency in operation.

    Many tasks performed within institutions of higher learning are of a routine clerical nature that could be better handled by the use of computers. In addition to merely supplementing manpower with computing power (mechanization), many functions could be accomplished by more efficient methods utilizing the capabilities of the computer to the greatest possible extent (automation).
It is recommended that state supported institutions of higher learning be encouraged to consider the use of computers to automate the routine administrative functions of the institutions, such as registration, grade reporting, payroll, and other functions as they become apparent.

14. More information is available today than ever before concerning institutional operations. The speed and flexibility of the computer will permit administrators to utilize this data to become more cognizant of the manner in which the institutions function. When such computer analysis is properly provided and wisely used as a basis for decision making, efficient management of the institution is greatly enhanced.
It is recommended that institutions of higher learning be encouraged to integrate computers into the management function.

15. Each year the colleges and universities of Texas answer numerous requests for information from the state. The manpower required to satisfy these requests is a significant expense to the institution concerned. Once the request is answered and the results are forwarded to the requesting agency, the information collected is essentially useless because it can be retrieved only on the criterion by which it was obtained. If, on the other hand, all requests for information were handled by computer methods, a number of significant advantages could be recognized.
It is recommended that requests for information directed to the institutions of higher learning by the state be structured to encourage the use of computers for response.

16. One of the first applications an institution with a newly acquired computer attempts is administrative data processing. As the situation now exists, formulation of administrative data bases follows no particular pattern. These data bases are conceived and built to meet the particular requirements of the organization and may be of no value outside the institution. This becomes readily apparent when information is requested by any outside agency and the institution is unable to comply using the existing data. This situation could be improved appreciably if guidelines for needed data bases were provided by the state.
It is recommended that the institutions of higher education be provided with guidelines and definitions of data bases needed by the state.

17. The role of computers in the Texas System of Higher Education will become even more critical because of accelerated growth in the approaching years. It is essential that adequate provision, administration, and use of computer facilities be insured. This can be accomplished only if effective policies governing the use of computers exist on a statewide level.

It is recommended that the state establish an advisory group which is competent to provide continuing policy recommendations concerning the role of computers in the institutions of higher learning in Texas.

COMPUTING IN TEXAS HIGHER EDUCATION

In 1950 there were between 10 and 15 digital computer installations in the U. S. In five years this number grew to 1,000. By 1965 there were approximately 30,000 installations, with a conservative prediction of 50,000 computer facilities by 1970. The computer industry, including the manufacturers and users, employs approximately 270,000 persons working at a scholastic level associated with a bachelors degree or higher.

By 1970 this figure will probably reach between 900,000 and 1,000,000. On a slightly lower level, there are roughly 45,000 computer operators in the United States today. Estimates of requirements for 1970 run from a low of 80,000 to a high of 130,000. At present, computer operators generally have a high school education supplemented by on-the-job training. As the sophistication and complexity of computers and operating systems increases, however, there will be a greater need for operators with more rigorous and comprehensive training.

Only 1% of the universities and colleges in the U. S. have doctorate programs in computing, 3% confer masters degrees, 4% offer bachelors degrees, and 23% only teach courses.* It is evident, even from these sketchy statistics, that the institutions of higher learning must develop programs to educate the needed personnel to work in this new profession of computing.

In addition to the education of those individuals that will work in the field of computing, there is a growing need to provide supporting courses to persons who will utilize the computer to some extent in other fields.

One of the most lucid expressions of the utility of computers is contained in the PSAC report.* "Computing is not an esoteric or specialized activity; it is a versatile tool useful in any work with a factual or intellectual content. Computing is becoming almost as much a part of our working life as doing arithmetic or driving a car." Engineers, mathematicians, accountants, etc. will most certainly be interacting with the computer and using it as a tool in their professions.

The great bulk of the remaining students will probably never touch a computer, many may never even see one. However, the implications of the computer revolution on society are so far reaching that it is imperative for these students to have a general understanding of computers. This might be looked upon in the same manner that every college graduate is expected to know something of the socio-economic organization of our country.

Scarcely a day passes that each of us is not effected in some way by the computer; our checks are processed by computers, computers help us make long distance phone calls, they write out gas bills, make airline reservations, etc. These simple tasks are more important than the general public is aware or admits; furthermore, much more vital issues involving computers are being raised today.

There is a great deal of discussion as to whether there should be a national data bank with a complete dossier on each citizen of the country. Some people feel, in the not too distant future, money will become obsolete as the computer keeps track of credit. There are even some people who fear that computers will eventually completely regiment our lives.

Whether any of these future possibilities come to pass may well depend on how well equipped society is, in general, to decide if these possibilities are good or bad. The sad fact is that today, a vast majority of our society is unable to comprehend fully what these issues portend because they have absolutely no understanding of the social implications of the much misunderstood computer.

Realizing that a computer education must be provided by our colleges and universities, it is necessary to examine the resources required to effect this education. This set of resources was collectively called "adequate service" by the PSAC report and exists in only a small percentage of our institutions of higher learning at the present time. Adequate service should be available in each of them. A comprehensive explanation of the ingredients that constitute adequate service is presented in the PSAC report.

What is Adequate Service?

What is adequate college computing service today, 1966? Several things are essential even to the most modest user if the aim is education rather than hard knocks:

1. *Adequate instruction in and consultation concerning computing.* Besides a good introductory course, the student should have available adequate supple-

* Statistics obtained from "Computers on Campus," *College Management*, Vol. 2, No. 3 (March 1967), pp. 53–75.

* "Computers in Higher Education," report of the President's Science Advisory Committee, The White House, Washington, D.C. February, 1967.

mentary material, and someone available to help him when he has trouble. It is desirable that the operating system be kept up to date, but any changes in the system must be documented and users given help in adapting.

2. *Adequate software.* The writing of programs should be made as simple as possible. Failure to run should lead to good diagnostics. Various languages, and facilities for adding new languages, should run as a part of the operating system without delays or changes in operation.

3. *Reliable operation.* Interruptions are bound to occur because of equipment failure, and there will be occasional interruptions because of hardware or software changes. However, if students and faculty are expected to use computers routinely, operation of a center must not be interrupted significantly by computer science experiments, unusual scientific or accounting jobs, or when examination time takes away those students who help to run the center. As far as is physically possible, the computing center should be open to users on a regular schedule.

4. *A fast turn-around time.* Instantaneous response is an ideal. Overnight delay is hardly tolerable. A delay greater than overnight is not acceptable for most purposes.

This is what can be called adequate in 1966. Other desirable things are available now and will be essential before 1970. These include:

a. *Interactive remote consoles.* Those who have used them in undergraduate education are convinced that interactive consoles are superior to batch-processing operation. When using these consoles the student types a program and special commands to the computer and then receives a response from the computer while still seated at the typewriter. The response either points out errors or inconsistencies in the program or presents the results of the requested computation. This reduces the time required to prepare a correct program and provides immediate reinforcement to his learning process.

b. *Graphic output.* In many cases, graphs or scatter diagrams or drawings are more desirable than tabular printouts as output. Present equipment can produce such plots on 35 mm. microfilm negatives cheaply, quickly, and without laborious programming. The negatives can be used in a reader or large prints can be made as desired.

c. *Visual displays.* The immediate presentation of graphic data on a cathode-ray tube is an extremely powerful tool in teaching a large variety of subjects. It is used currently in many applications.

d. *New forms of input.* Many new applications or modes of operation require special input devices such as the following: (1) Direct connections allow data to be transmitted directly from experimental apparatus rather than by reading meters and typing the values into the computer. (2) A character recognition scanning device makes some typed or printed material available as input without requiring laborious key-punching. (3) A 'light pen' combined with a cathode-ray tube allows one to give directions to the computer by pointing at a selected portion of a display and allows one to draw input graphs.

It is interesting to note that the first item on the list of requirements is not a hardware device but a need for qualified faculty and staff. It is evident that the greatest problem to be overcome by the colleges and universities in the state will be the acquisition of enough competent personnel. The March, 1967, issue of *College Management*, contains a comprehensive survey of the use of computers in colleges today. A disturbing although not surprising fact that came to light as the first entry under the heading "Primary Problems with Computer," was "difficulty in obtaining staff for computer". This is an area where colleges are competing with industry for a limited number of qualified people. One method of alleviating this situation that has proved highly successful at a number of installations both in industry and education is to build from within. To be successful utilizing this "bootstrap" method, however, it is essential to obtain the best senior staff nucleus possible. These individuals will form the foundation of the data processing program at an installation. It may be necessary to pay unusually high salaries for these persons, but the investment for a fully qualified staff will be money well spent.

Once the senior staff of the computing center is available, they can establish an operational center that will produce a "pay off" for the institution's investment. Additional operational personnel and staff members can, to a great extent, be drawn from advanced graduate students. This approach to the problem has several side benefits in that it provides the student with valuable "hands-on" practical experience. By starting with the more menial tasks involved in a computer operation and "working his way up", he gains an appreciation of the tasks involved in the basic operations of a computer center. The student employees in the computer center are usually eager and hardworking. What they lack in experience is compensated by the generally high caliber of the individuals. As the student program progresses, the more outstanding

students can perform in more responsible positions, such as supervisors, programmers, and some as systems analysts. The key to building a productive computing center is to build slowly on a good foundation. The senior staff supervising this type of operation must necessarily be the best obtainable.

Computing is not a Spectator Sport

Assuming that an adequately qualified senior staff can be obtained, some means must be devised to gain access to the computer itself. This does not mean that every institution of higher learning must have a multimillion dollar computer on campus. However, every institution in the state could certainly justify some in-house computing capability to handle routine tasks and a limited amount of instruction.

One method of obtaining this computing capability at a comparatively low cost is by utilizing second generation computers that have been replaced at other installations. Regardless of what many people think about "obsolete" equipment on campus, these machines could accomplish a great deal, for the institutions that currently have no computing, by teaching basic concepts. Administrative applications can be processed nearly as well on a second generation computer as they can on a third generation machine of comparable size. Useful programming could be taught utilizing higher level languages. These source languages are basically the same on both generations. For those problems that require a greater computing capability than is available on these machines, larger computers could be utilized on the campuses of the more highly developed institutions within a reasonable geographic region.

Computing is Not a Luxury

The digital computer has long since left the realm of a luxury and has become as much an essential tool of education as is the library. Although many educators feel this to be true, they are unable to find the money in an already committed budget to pay for the computer. Computers are expensive both initially and as a continuing expenditure.

The initial installation of a computer on campus entails a large expenditure of funds for site preparation, procurement of miscellaneous supplementary equipment, and seemingly non-productive developmental work. This initial expenditure, however, is just the beginning. Computing is a recurring expense the same as gas, water, and electricity. The computer center must be staffed, a qualified faculty must be obtained, monthly rent or maintenance costs must be paid, and software must continue to be developed. Every three to five years the computer will probably be replaced by a more advanced larger model. It is for these reasons that many colleges and universities are without adequate computing. (It seems to be a paradoxical situation when on the one hand we can't afford to have computers and on the other we can't afford not to have them.) Many institutions in the state are simply unable to allocate enough resources to finance the computer.

It is for these reasons we believe it is essential that computer support be made a line item in the budget of every state supported institution of higher learning in Texas. To do this, however, there must be some equitable method of determining the amount to be allocated to each institution. A reasonable approach to this situation seems to be a formula system similar to those used in other areas, in the current budget process. The formula developed would have to provide for some base that would allow the smaller institution to have some computing capability. At the same time, it must provide for the growth of newly established installations and it must promote the continued achievement of those centers which presently have well developed computer facilities. Careful consideration must be given to the items and to weighting-factors of items included in this formulation.

Centralized Facility

As one can see, cost is a major factor governing the type and size of computing facilities in the system of higher education. With this fact in mind, an objective study of the proper organizational structure for the computer leads one to the idea of a central computer center serving all users.

The average cost per computation decreases as the computer size increases. Thus one large computer can do more work than many small computers totaling the same cost. Also with many small facilities, duplication of staff, equipment, and effort is unavoidable, again bringing added expense to an already expensive operation.

In a report to the University of California System*, five arguments for having special-purpose facilities rather than one centralized computer were discussed:

1. Control over service. Dissatisfaction with turn-around time and general service aspects of the general purpose facility to the extent that users decide to raise funds for a computer they can control directly.

2. Magnitude of user requirements. One or two investigators may generate sufficient work-loads to adequately utilize a computer for their exclusive use.

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* "University of California Computer Study," Management Analysis Center, Inc., Cambridge, Mass., October 31, 1966.

3. Special programming requirement. Some types of research, in the medical field, for example, may require complex and unique programs for data manipulation. Better control for equipment would assure better maintenance and operation of these programs.

4. Experimental apparatus In some research, a computer is necessarily an integral part of the apparatus as an on-line control device or as the subject of the research itself.

5. Specific funding. The funding agency may fund the acquisition of equipment in order to encourage the greater utilization of computers. The equipment, may then be made available to investigators at no extra charge. A donor may even offer equipment rather than money where this is more convenient.

Through effective management of a general purpose computing facility most of these special requirements can be satisfied. Certainly, proper planning and scheduling can assure adequate service to all users. In most cases even large loads can be handled by the central facility by careful coordination between center and user. The user can also maintain his own programming staff, if necessary, and still use the central facility effectively. Even in the case of specific funding, the grantor could be urged to provide funds for utilizing the central facility. In some of the modern computers, on-line control is also possible for experiments while general purpose computing is being done. In each case the central facility frees the researchers from the managerial problems of computer center operation (which are formidable).

The idea of a general purpose computing facility does not necessarily mean one computer, although one if often sufficient; it refers rather to centralized management of whatever computer facilities are available. The benefit of a centralized facility can be obtained through common management of a group of computers. Good management is the key ingredient in the success of the centralized facility.

Administration

When speaking of centralized computing facilities, emphasis is placed on the management. In addition, the goal of the facility is simply service to the institution. For the management to be effective in this role of service, the computing facility should be a separate unit within the institution as opposed to being a subdivision of some organization that may be partial to special interests. By placing the control of the facility under a ranking administrator, this environment can better support the interest of the institution as a whole. In the same vein, all areas can be assured the access they require.

The presence of a ranking administrator can lend much to the success of a progressive computer center. His influence in acquiring funds for an expensive, yet essential, operation cannot be overemphasized. Also, this high level of communication available to the computer center tends to be increasingly important as the computer is relied upon more and more heavily in the day-to-day operation and planning of the institution. An opportunity is afforded here to merge the capability of the computer with the foresight of the institutional management team to obtain what might best be called efficiency.

We Need Solutions for Today and the Future

The "network" approach appears to offer an efficient method to provide adequate computing capability to all institutions of higher learning in Texas. The network would allow smaller institutions to use their small to medium scale computers to process the majority of their work. Those jobs that could not be handled adequately by the local computers could be processed at larger installations. Examination of the computing capability found at each of the institutions of higher learning in Texas, would display a spectrum of expertises that varies from literally nothing to several centers who compare favorably to the best university computer centers in the country. The more highly developed centers in the state have the capability to assist the less fortunate institutions.

While it is true that the network concept offers promise for Texas' computing in the future, of greater importance is the fact that networks may provide an immediate solution to many of the already existing problems. Networks could be implemented in the immediate future utilizing common carriers for the transportation of programs and data to the computer and the return of the results. This technique has proven quite successful in Texas previously and is still being utilized by a few institutions. This "greyhound network" could form the basis for eventual hook-up of computer-to-computer networks within the state by helping alleviate some fundamental problems of coordination now.

This process should *not,* however, impede the procurement of computers for those institutions presently without them. It is not feasible at the present time (or in the foreseeable future) to develop a comprehensive capability in computing utilizing remote techniques. Machines located at other institutions can provide two funcitons for those campuses without computers or with small computers. For those that have no computing, it can be a beginning of a developmental effort until their own machines are installed. For those institutions with small to medium computers, it provides access to high powered computing equipment that they need only occasionally.

At the present time, it appears the network problem could best be handled on a regional basis as opposed to the statewide concept. It seems there are three basic reasons for this: 1) the physical size of the state, 2) the large number of schools involved, 3) the lack of practical experience in extremely large computer networks. All three of these reasons point to a major problem of coordination and actual operation of the network. The regional organization appears to be a more practical approach to establish an efficient method of providing adequate computing capability to all institutions of higher learning in the state.

The network concept discussed thus far has been primarily concerned with aiding the smaller user. Before a network could be established, however, some incentive must be provided for those larger installations that will be in a supporting role.

COMPUTERS AND TEACHING

The requirement for computers in higher education reaches into every field of knowledge. It is generally accepted that essentially all university and college students must acquire some basic understanding of digital computation. The overall use of computing in both industry and government is dependent on educational computing not only for training of computer scientists, but for instilling in graduates of all disciplines an adequate knowledge of computing in their particular field.

It is the responsibility of academic computing to insure that these needs are met. Computing must be available which is adequate for education in computer sciences as well as education in other fields. Unhappily, in the majority of colleges and universities instruction in the use of computers and computing is neither widespread nor effective.

Obviously, the lack of qualified instructors, inadequate computing facilities, or the pressures of computing curriculum requirements make such moves difficult for many colleges and universities. Yet a few institutions are considering making a programming course compulsory for all students, feeling such courses offer the only acceptable introduction to the world of computers.

As the computer becomes more and more an integral part of man's environment, instructional programs designed to accomplish four major objectives will be needed. (1) to provide programs at the doctoral level which will educate computer scientists and foster advanced development of both equipment and hardware, (2) to educate computer specialists, both operators and systems analysts, to meet growing technological demands, (3) to educate professionals to use the computer as an essential tool of their trade, and (4) to make computers familiar tools to all students in an increasingly automation-oriented culture.

Computers and Students

Computers and computing in teaching may be generally separated into two categories:

1. As a *tool* of instruction;
2. As a *subject* of instruction.

While a major purpose of this report is the investigation of the teaching of computers as a subject of instruction, the other uses of computers as tools of instruction will be briefly reviewed. It is important that the distinction between these two categories be clearly understood.

A Tool of Instruction

In a very special sense, a computer can be used to provide an environment for learning. This is accomplished by programming the computer to perform most or all of the tedious calculation required for solution to complex problems. The student is then freed from the drudgery of the mechanics of reaching the solution and is able to concentrate on evaluating the solution obtained.

The use of computer-based simulations has also proved to be a powerful use of the computer as a teaching tool. A system which the students are to study is simulated. The students then explore the simulated system testing it under varying conditions as they never could the real system. Perhaps the most widely known example of such use is "management games", or simulations of business organization. Such use of computers has a vast effect on the basic approach used in teaching; instead of trivial and contrived problems, real-life problems can be presented to the student.

While the use of computers in simulation and solution of complex mathematical and scientific student problems is becoming widespread, an even more exciting use is being developed in computer-aided instruction. Computer-aided instruction utilizes the capabilities of the computer to select, present, and evaluate responses to subject matter. The student interacts with the computer through a teaching terminal which may be either a simple typewriter-type instrument or a complex audio visual display incorporating both audio and pictorial response. The promise of this instructional medium is its unique capacity for interaction with the student as an individual. The computer's selective ability operates in a number of ways in adapting the instruction to the individual students' needs.

The field of computer-aided instruction is, however, in period of early experimentation. Many problems impede further progress, such as the large expense of equipment, the expense of developing viable software and course materials, and the basic need for a better understanding of instructional technology.

The potential benefits of full development of the instructional uses just described suggest a dimension of education in the future which can only be imagined today. It is this potential which demands that the educational process, as it now exists, be thoroughly reviewed. We must

insure that students being trained today have the best possible preparation to carry on the research of tomorrow.

If the most is to be made of limited time—and every new subject introduced into the college curriculum now faces rigorous competition from other subjects which can make excellent claims on the students' time—it is important that computers be used to extend the students' grasp of other subject matter. In effecting this goal, it is not enough that computers are used as mere aids, albeit very sophisticated, for passive instruction. Every student must be educated in computing to an extent that will allow him to use the computer in unique ways.

A Subject of Instruction

The common characteristic of all types of training in computing is that the student is gaining understanding of and facility with a tool. There are four distinct levels of instruction, however, which must be available to qualified students: (1) training computer scientists; (2) training computer specialists; (3) training professional users; and (4) general education.

Training computer scientist. While computer technology has made unprecedented progress in the last decade, this very progress has unhappily outstripped man's ability to utilize completely the computing machines he can build. There is a growing body of research (and more is urgently needed) in the use of computers—in man-machine systems, in the development of programming systems, in interactive use of computers, in theories of programming, in high-order languages, in the use of networks, and in the use of commonly shared data banks. More research into such problems as the simulation of thought process and human learning and the attempts to teach computers used as both a subject and a tool or research is needed.

Then, too, there is the general field of research in the role of computers, of robots and automation in general, and in social, political, linguistic, literary, and economic systems. Such research may develop still more applications and the need for more trained scientists to explore new and presently unknown areas of computer science.

The computer scientists who must provide the impetus for such basic research is in critical shortage. Such individuals, normally associated with programs at the doctoral level and above, must be provided training which will qualify them to conduct research enabling human beings not only to effectively use computers but to continue the rapid development of the past.

The development of Ph.D. programs suitable for the training of computer scientists is possible only in major institutions of higher learning. It is only in such environments that the necessary "centers of excellence" can be established. The quality of computer facilities necessary for such programs is of critical importance. For first-rate doctoral work, a computing facility which is at the forefront of the art is essential. Where such facilities are not now a part of major institutional programs, immediate action must be initiated to insure both the establishment of doctoral level programs and corresponding adequate computing facilities.

Training computer specialists. The fact that over 80 percent of the world's computer systems are installed in the United States underscores a major responsibility of institutions of higher learning. Educationally qualified men, from computer operators to systems analysts, are needed to fill the technological demands of industry, government, and education itself. The need for programmers, analysts, and computer operators in industry has placed pressure on the institutions of higher learning to produce qualified personnel to meet the demand.

The level of education required for different types of computer specialists will, by its nature and complexity, be directly related to the available computer facility. Training of computer operators, for example, can be offered at every school that has a computer. Specific training programs for operators, however, should be primarily associated with smaller facilities, such as the junior colleges could provide.

Other men must be trained to understand sophisticated hardware and software very thoroughly. Such education not only supplies the computer industry with needed expert manpower; it strongly influences progress in both hardware and software. This type of comprehensive instruction calls for access to and interaction with an excellent computer facility. In order to produce the computer experts who are needed, we must have excellent computer science departments at a number of schools.

It is imperative that computer science departments be established at those larger four-year institutions which have adequate computing resources to support an advanced instructional program.

In considering the establishment of a number of computer science departments, a word of caution is in order. The quality of an instructional program can vary, and it is desirable that course offerings and curriculums be subject to continuing review to insure that the individual institution's resources can support adequately a given level of instruction.

Training professional users. Students in such professional majors as business, engineering, and science must be trained in the use of computers as essential tools of their trades. Their future careers will require such knowledge. Work on current studies and research will be greatly facilitated. For those students who can see direct applica-

tion of computing in their work, computer science will mean more than merely identifying concepts and formulating programs.

General Education. Leaders in many forward looking educational institutions realize that all students should learn something about computers. No matter what his specialty, the student must be involved in the experience of using computers in learning as well as in doing.

Because of the expense of equipment and staff most junior colleges and small four-year colleges have not provided this involvement. Even many of the larger colleges and universities are not providing adequate instruction to a majority of all students in the use of computing in some part of their course work.

Computers and Faculty

If the rapidly expanded use of the computer creates problems in the training of students, so does it pose a problem for faculty members most of whom were educated prior to the present computer revolution. More importantly, the faculty will often determine the rate at which computing is introduced into the more general levels of instruction. In any realistic discussion of computers as a subject of instruction, the problems of educating the faculty cannot be overlooked.

In general, faculty education required for the introduction of computing is the basic education associated with any substantial revision of course material. Planning new problems and approaches and integrating them into course revisions requires a large amount of time and a subsequent reduction of available teaching staff. The rate of revision is also influenced by the interest in and understanding of the computer as well as the availability of facilities.

It is very important for the faculty to recognize that the time required to cross a significant threshold of understanding so that one may begin to do useful work for himself and his students is very low compared to a discipline such as mathematics or language.

The role of the administration is of the greatest importance in providing opportunities for learning by the faculty. When adequate computer facilities are provided in our colleges and universities, it is essential for the general faculty to be able to understand and use computers in their teaching.

COMPUTERS AND RESEARCH

Research is the careful, systematic, patient study and investigation in some field of knowledge, undertaken, to isolate facts or principles. As society looks more and more to the educational world for this type of study, one may visualize a day when almost all important research is confined within the bounds of educational institutions. With this burden of responsibility, higher education must be forever searching for necessary resources to conduct research and better methods of utilizing these resources efficiently. The computer has made a significant contribution both as a resource and as an aid in attaining greater efficiency.

Computers are already doing tremendous tasks such as gathering and analyzing data from scientific experiments. Many experiments are being completely controlled by a computer, eliminating many possible sources of error. Some experiments, not feasible or possible in the laboratory, are simulated by the computer and valuable results obtained which apply to physical problems at a greatly reduced use of time and money. All of these are possible because of the computer's speed, its capability to handle large amounts of data, its power of decision-making, and most of all the ingenuity and technical skills of the people who program the computer. Without the guiding hand of a skilled computer specialist, even the most sophisticated computers are useless.

Computational Research. When one speaks of computers and research, two logical divisions appear. On one hand, the computer may be used as a tool in support of research. On the other, the research may be seeking better usage of the computer. Both of these divisions are represented in the Texas System of Higher Education, although the latter applies to only a very few institutions and a small amount of research.

As another piece of research equipment, the computer has simplified procedures and made possible techniques which heretofore were impossible. In the area of mathematics, for example, some numerical computer solutions are possible for problems for which no known analytical solution exists. In other cases the computer does calculations which are too lengthy to even attempt manually.

Computer-Oriented Research. The power of computer technology has only been realized to a small degree. To fully utilize the capacity of the computer or even realize the opportunities, much research must be done. Software must be developed to make use of the new equipment emerging everyday. In general, computer-oriented research is sorely lacking in Texas higher education.

This type of research is necessarily dependent upon advanced computing equipment and capable computer specialists. These factors go hand in hand with a large institution capable of justifying a powerful computer and a professional staff for its utilization. An institution with such assets will probably support a computer science program, which further enhances the possibilities for computer-oriented research. The best results can thus be obtained by a concentrated program of computer-oriented research in a few highly qualified institutions with graduate computer science programs.

One example of this type of research is the development of new computer languages for application to special classes of problems. Another area of needed research is in the design of hardware and software to improve the speed and convenience of data input and data presentation. Both areas of research compliment the expanding field of information science.

Planning. As the research work in the system of higher education increases its dependence upon computers for support, long range planning is essential to coordinate the research with the changing technology in the computer field. Planning will allow research activities to keep up with the technology and even to influence its development in line with research needs.

A statement by the Management Analysis Center in a report to the California Educational System says, "One of the most striking aspects of the present situation is the almost complete absence of planning." This statement also applies to some degree to the Texas System of Higher Education.

Cooperation. Research is normally considered to be original work, but too often it is original only in the eyes of the individuals doing the research. The identical work may be carried on elsewhere with no intercommunication or it may even have been performed by some previous work group. Unfortunately, this situation often exists even within the framework of one educational institution. The resources available are much too small to permit such a violation of common sense. In some cases, of course, communication is inhibited by the desires of the funding agency. This problem is more complex but represents only a small portion of the overall communication problem.

A system of information interchange can only help the

quality and prestige of Texas educational institutions. Almost all research requires reports of activities whether it be graduate research toward an advanced degree or externally sponsored research. Certain basic information is common to all such activities and would be relatively easy to circulate within the educational system. The computer can be used to collect and disseminate information on a regular basis to all persons who might benefit from it.

The main barrier to a successful information system is the people involved. Like any cooperative effort, a system such as this must have the confidence and support of all its participants. There must also be some controlling group to gather data and make it available in usable form to the group. For general acceptance, the group should be an aggregate of the members themselves and not a state agency.

Centralization. Except in special circumstances, research activities can be conducted on the central general-purpose computer on the campus. The researcher should not be burdened with the management of a computer, which is a formidable task. Under proper management the central facility can furnish the researcher with adequate turnaround time to support his research. The central facility will undoubtedly have a larger, more powerful computer than the researcher could possible justify for himself alone.

Many large research groups desire a separate special-purpose facility to allow them greater control and flexibility. In most cases, however, they can be well-served by a central facility at a much lower cost. Admittedly there are situations where special equipment cannot be feasibly attached to the central computer and a special-purpose facility is necessary. Fortunately, these are the exception rather than the rule.

Funding. Corresponding to growing research activities is the growing need for financial support to pay for expensive computing requirements. These funds may come from government or private industry to support specific research (sponsored) or as a general appropriation from the government (non-sponsored). The government will need to increase its support of research in the coming years to take advantage of the new opportunities made possible by computer technology. More funds are also being made available by private industry to support the expanding requirements for computers in research programs.

In the area of governmental support, one problem is especially noteworthy. Due to indirect funding of non-sponsored research, allowing any additional computer time to users who have depleted their funds results in an overall decrease in the total funds allocated. In this case the usage is increased without any additional cost thus lowering the average cost per user. Since the average cost is used to determine funding, less money is allocated. To avoid this unreasonable situation, a separate allocation should be made of a definite amount for computer use in non-sponsored research. In any case, each research activity should pay for its computer time on a direct-cost basis.

Progress. The importance of research both in computer science and computer applications has been emphasized. Too often, however, the task at hand takes precedent over research into the future. In view of this situation a certain percentage of the total resources available should be allocated to a definite research program. The gathering of new ideas, the study of new concepts, and the forward look toward future problems are all too important to be relegated to a back seat in the educational program. The progressive institution can move forward through a good research program and will likely move backward in its absence.

COMPUTERS AND UNIVERSITY ADMINISTRATION

Shortly after World War II, two events occurred which could affect almost every phase of our society. One was the development of the electronic computers. The other was the development of the field of management science. These two developments, when coupled, form the basis for a tool that no up-to-date administrator can afford to ignore.

The computer was first developed to accomplish such mundane tasks as ballistic calculations, census counting, and other repetitive operations. As the sophistication of the computer increased, the problems presented for computer solution became more varied and its sphere of influence reached into all segments of the economy. Quite naturally, one of the first areas affected was that of routine office work, where the computer was used to "mechanize" functions that had previously been done by hand. The prime motivation for this step was increased productivity. This was certainly reason enough, particularly when added to the increased accuracy of the computer. However, there were greater benefits to be acquired when applications went beyond mechanization and problems that were heretofore insoluble became an operational reality. It was at this point that management science left the realm of a curiosity and began playing a significant role in our society.

The colleges and universities of Texas, as well as in the nation, are facing an unprecedented challenge in providing a quality education to the large number of students seeking enrollment. This challenge must be met and it must necessarily be met with limited resources. Computers and management science techniques can aid in this task by providing information, to administrators at all levels, that will allow them to make a more efficient allocation of the resources available. Unfortunately, the colleges and universities in Texas are more than a little behind in the use of computer for administrative and management purposes. Certainly many of the institutions in the State are using computers to register students, produce payrolls, and keep track of the various inventories they must maintain. A few (too few) have gone beyond this point. A number of the smaller institutions have no computing capability on their campus and the only mechanization they can claim is through the use of accounting machines and desk calculators.

It is imperative that computers be placed on campuses that currently are without computing capability and that the administrators of these institutions, as well as the faculty members and researchers, make use of them. At the most elemental level, there are two prime reasons for the use of computers in university administration.

Increased Productivity will allow the same functions that are now being performed by manual means to be handled by the computer, increasing the potential capability of these selected areas. The results from any specific application of computers are difficult to determine; they may free personnel to work in other areas, they may increase the production without a comparable increase in personnel. This is not to advocate the blind mechanization of every routine function of a university. Nevertheless, each task that is being considered for mechanization should be closely studied to determine exactly what is being accomplished and how it is being done prior to the design of a computerized system to replace it. Many times this "systems study" will reveal many facts that will cause the function to be reorganized and simplified to the extent that it is undesirable to use the computer at that point in time. To paraphrase a familiar saying, there is nothing quite so useless as doing something efficiently, that shouldn't be done at all.

"Better" management information is the prime reason for utilizing computer techniques. "Better management *information*" refers to *more information, more accurate information, more timely information, more analysis and reduction of information*. The use of this better information is vitally important to the operation of our institutions of higher learning.

While it is not necessarily true that an individual will always make the best decision if provided with the right information, it is, however, much more likely that he will make a better decision. There are a few talented individuals who, through years of experience, intelligence, and a little luck will unerringly make the right decision. Unfortunately, these people are difficult to find. Even if they were available, consider what they could do if provided with a reasonable amount of information to give them a deeper insight into the problems with which they are concerned.

A Computer is not Enough

The production of good management information is certainly possible through the application of computer

techniques; however, simply having computers on campus and mechanizing a few functions of the university is not enough. In order to provide a successful administrative data processing capability on a campus, there are a number of requirements that must be satisfied.

A Qualified Staff. In the same manner that an institution strives to acquire the highest quality faculty members and administrators, so should it obtain the best possible staff for its data processing facility. This is particularly important with respect to the director and senior staff of the center. These people must be technically competent in computing and be capable of working with all phases of the university operation. The university is dependent on the staff of the computer center to design and implement each of the desired administrative systems. This will enhance to a great extent their ability to work with, learn from, and educate the users of each administrative system. In addition to designing a system to meet a specific need, the computer center personnel must be aware of other systems, both under development and being planned. These people must fit these systems together to provide coordinated administrative information above the level of a single system.

A Willing User. Realistically speaking, before any administrative system will operate successfully, it must have the active cooperation of the user of the system. For example, if it were desirable to implement a mechanized class scheduling system, the computer center must have the complete cooperation of the registrar's office. This can be accomplished if the user realizes a need for the service and can be educated to the fact that a data processing center is a service agency for the campus, with a prime mission of serving other agencies on campus.

Acceptance by the Administration. The higher administrative officers of a university can do much to foster the proper growth of a data processing center by encouraging its use and by properly utilizing the reports generated by the facility. When the center first begins operation, there will probably be little, if any, information in which anyone above the level of middle management would be interested. However, as the center develops and information from more than one system can be combined to cover broader areas, many valuable facts that need to be considered for policy decisions are made available. This is the point at which the high level administrator will begin to realize a "payoff". To make the most of this payoff the administrator must utilize the information with which he is supplied. One of the most fruitless situations that can arise is to produce management reports only to have them ignored.

Communication. A successful administrative data processing center can be greatly enhanced by communication and cooperation between high level administration, the user (middle management), and the data processing personnel. This communication can bring to the surface problems faced by the administration of the university at various levels and provide a better understanding of what the computer can do for them. The computer is not the panacea for all the ills of a university but it can be a valuable asset and will be more valuable if there is a free interchange of communication between the data processing center and the other area of the university.

A Still Broader View. In the same manner that a university administrator is in a better decision making position when armed with the necessary information, so are the administrators on the state level, who must manage not a single university or university system but the entire state-wide educational system. To obtain the desired information, the state government levies reporting requirements on the state-supported institutions. Many of these required reports are well established with respect to both content and definition of terms. This is the case of registration information. There are two beneficial results from this type of reporting requirement; 1) it encourages the use of computers to process the information and produce the required reports and 2) it specifies to some degree the information required in the data base. These two results are far more significant than they appear on the surface. When a university collects, processes, and prepares reports by the use of computers, the administration of the university is encouraged to utilize the information with which they are furnished to provide a firm foundation for decision making. When common information is requested from each of the state's institutions of higher learning, it tends to promote compatible data bases at all institutions with common definitions for the items contained therein. When these definitions are so specified, the effort required of the institution of responding to the request is reduced. This can become a significant factor. Unfortunately, there are many areas into which the state government periodically inquires that are not so well defined. A few of these are research, extension, and inquiries about the development of the institution in some program area, such as water resources. This report strongly recommends the state government establish guidelines as to its areas of interest and definitions of items of information to be requested for the institutions of higher learning in the state. The report further recommends that these guidelines be formed in such a manner as to encourage the use of data processing techniques to respond. This will accrue benefits at both the state and institutional level. The information provided to the state will be more timely, more accurate, and in all likelihood more compatible, if prepared by the computer. These same benefits, and more,

could be realized by the institution. The data base would be established for use in other areas and could provide information to other systems for overall management reports. The existence of the data base, once established, could substantially reduce the effort and expenditure, both in dollars and manpower, by the institutions in responding to the request.

The Time for Action. The ideas presented in this chapter are far from the realm of day dreaming or wishful thinking. The integration of computing techniques into the management function of increased efficiency, is a well proven and highly successful fact. The institutions in the State of Texas should make the most of these techniques.

TEXAS AND COMPUTING NATIONALLY

The next few years will be a critical period in the Texas System of Higher Education. Computer technology, in its relation to education, is increasing in significance at a rapid pace. To achieve and maintain a position of excellence within the educational computing community, a plan must be designed to apply this technology. In fact, one might go one step further and say that we must contribute to the new technology or be left behind.

The position now held by the Texas System of Higher Education in the field of educational computing needs to be examined. The present outlook is deceivingly optimistic. When compared to the national average* in computing power and money spent for computation and computerized applications, Texas is well above average. Size, in itself, however, is no measure of quality or any assurance of future progress. Progress and quality depend on the initiative and creativity of knowledgeable people.

As pointed to in the Rosser Report,† universities have greatly underestimated the need for training in connection with computers. It is true that universities lacked adequate support, but they could probably have obtained that support had they stressed the need and presented a well-planned program.

In an article in "College-Management",‡ 11–13% of all universities have bachelors or masters level programs in some phase of computer science. In addition, only 23% of all colleges and universities combined, teach any computer courses. Texas institutions, recognizing the importance of computer training, having exceeded these averages. The rate with which the system progresses will remain, however, the important factor in judging the quality of the educational program.

Some interesting statistics were reported to the Southern Regional Education Board* the use of computers for research and instruction. During the next few years, nationwide, 81 schools plan to offer bachelors degrees in computer science, 59 schools plan masters programs and 26 plan doctorate programs. In Texas, by comparison at least 9 institutions presently have or are planning various levels of Computer Science degrees during the next few years. In 1964–65 this involved over 1000 students in graduate programs and 4000 in undergraduate programs across the nation. It is estimated that these figures will at least triple by 1968–69. For degrees in other fields which require some computing knowledge, the number of students involved is expected to be over 80,000 in graduate and 350,000 in undergraduate programs by 1968–69.

Examining the number of public educational institutions in the country and estimated number of institutions with computers, it is interesting to find that 97% of all universities will have one or more computers by 1969. 55% of other 4-year colleges and 35% of the 2-year colleges will have computers. This represents a 12% increase in university computers between 1965 and 1969, 48% increase in 4-year institutions, and 105% in 2-year colleges. Texas compares favorably with all these statistics.

In 1963, Texas was third only to California and New York in the number of colleges with computers.* This position seems to be remaining constant with computer hardware. One thought is worth considering, however: how does the Texas System of Higher Education compare in research applications, new innovations in computer uses, and planning for future developments? That the computer must play an important part in any planning toward the future of education is exemplified by a report to the University of California System† on the use and management of computers throughout the university system.

There are many other examples of forward-thinking institutions planning for better uses of the computer. The important point is that the Texas System of Higher Education must do as well.

Thus the Texas Educational System bears a responsibility to itself and society to maintain an environment conducive to excellence in the computing sciences, and, in addition, to maintain the computer as a tool for more efficient and effective college operation. The latter, due to its pressing nature, will surely be accomplished with only a small amount of encouragement. Other states seem to be advancing quite rapidly with new innovations in computer use through large research programs. Our responsibility requires no less. Plans must be made and concise programs must be established and funded to make better use of the computer in future years.

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* "Computers on Campus", *College Management,* Vol. 2, No. 3, (March 1967), pp. 53–75.

* "Digital Computer Needs in Universities and Colleges", Washington, D.C., 1964.

‡ *Op. cit.*

* Hamblen, John W., "Computers in Higher Education," A report to the Southern Regional Education Board, Atlanta, Georgia, August, 1967.

* "Digital Computer Needs in Universities and Colleges", Washington, D.C., 1964.

† "University of California Computer Study", Management Analysis Center, Inc., Cambridge, Mass., October 31, 1966.

FUTURE TRENDS IN COMPUTING

In just over 20 years the field of computing has produced three generations of equipment. The third generation computers have become well established only in the last year and we are beginning to hear rumors of the fourth generation with this rapid growth, computers of 1980 may be unrecognizable as computers, as we know them today.

The specific technological advances that will appear in the future may be difficult to predict, however, there are some general improvements in computing that can be forecast with reasonable assurance because of present requirements for them and the subsequent research being done. These improvements must necessarily be concerned with both hardware and software.

In hardware, there appears to be four major areas where improvements will be made.

1. *Larger memories.* One of the most impressive areas of development in computing in the past twenty years has been the increase of storage capacity and speed of access. The standard ferrite core memories used by the majority of computer manufacturers today has made possible very rapid retrieval of reasonable amounts of information. Memories of this type that contain from one-half million to over a million characters of information are not uncommon today. From a technical standpoint it is quite possible to increase the capacity of core storage substantially, however, the cost is prohibitive. As a solution to the problem of storing large amounts of directly accessible information at a more acceptable cost, the manufacturers are producing devices which can store up to 400 million characters of information by a sacrifice in access time. Such devices as the magnetic disks, magnetic drums and data cells have opened the doors to computing for many applications. The capacity of these devices coupled with the lower speeds of access are still such that many advances in computing techniques are being impeded.

   Research is being done today on completely new approaches to increasing the size and speed of memories at a lower cost. One method that was demonstrated as early as 1960 is thermoplastic recording. This system allows nearly 15 million bits of information to be contained on a 4×4 in. plate. The high density of storage is one of the basic problems in making it work.

   Photoscopic disks are still another approach to the problem. This technique is based on placing spots photographically on a glass disk. IBM at one time announced a trillion-bit photoscopic memory for work in the area of language translation. A major fault with this system is that once it is impressed, the information is permanent.

   Other techniques under experimentation include electron-beam-machined memories and photochromic phenomenon. Some of these approaches to the memory problem may be the solution; on the other hand none of them may prove practical. Nevertheless, some solution must be found to make feasible many applications that are being proposed today.

2. *Improved Speed.* Many of the applications that are in dire need of larger memories will also require faster computing speeds. This does not necessarily mean the computing required will take an unusually long period, but the compute time is too great for the particular reaction time requirements.

   Much of the work being done in improving memories is also applicable to the speed problem. For example, thin film memories are being used to a limited degree by Univac with some computers currently on the market. Thin film magnetics might bring about a significant advance in speed if all-magnetic circuits can be proved feasible and if adequate production facilities can be achieved.

   The tunnel (Esaki) diode may possibly prove to be a major breakthrough for computer circuity. A one nanosecond (billionth of a second) operation time has been established as a definite possibility utilizing this component. This is 500 to 1000 times faster than the fastest computers on the market today. Much needs to be done in the refinement of design, the techniques of construction, and the maintenance of tolerances.

   Another method for increasing internal computer speeds is superconductivity. This is a property of certain metals which at very low temperatures causes electrical resistence to disappear completely. The primary problem is maintaining these low temperatures in an economical manner.

   Microwave technology offers promise of circuit switching (a fundamental process in computer operation) to be accomplished in less than a nanosecond.

Facilities, however, are lacking that can produce sufficient quantities of needed variable-capacity diodes (the essential component of this system). Little microwave circuit design has been accomplished that is relevant to the computer problem and generators have yet to be designed for the production and distribution of sufficient microwave power at the high frequencies required.

3. *Subsystems.* A major problem that has faced the person who wished to utilize the computer from the advent of computing to the present time is the man-machine interface, or, how the human physically communicates with computer. There have been a number of advances in this area in recent years that, hopefully, will greatly reduce this problem.

   Magnetic ink character recognition is being utilized by the banking system on a massive scale. Optical character recognition devices are now on the market that do quite well in restricted use. These devices at present are very reliable and are able to recognize most type fonts used in the U. S. and have the capacity of learning to recognize new fonts by means of submitting an ordered sample of the alphabet. Equipment capable of reliable interpretation of hand-writing appears to be for the more distant future. Research is being done in the area of machines response to the spoken word, but again this appears not to be a consideration in the near future.

4. *Organization.* The greatest advances in computers may be, however, in a completely new approach to the design of the machine. Many people feel that since von Neumann, insufficient study has been devoted to the logical organization of computers.

   One such effort in changing the computer's organization is time sharing. The results of this endeavor is very much in evidence today. Although time sharing has fallen short of the hopes of many people, great strides have been made and should continue to be made in the near future.

   Computer to computer communication is another logical reorganization of computers that has proven worthwhile even though there are still many problems connected with it. This integration of computing capability is still relatively new but offers much promise for greatly increasing the computer's utility.

   Variable structured computers (computers that by programming or by external control can have the instructions they execute modified) appeared in a very limited extent in third generation computing equipment through the use of read only storage in the IBM System/360 line. This concept could conceivably allow each type of application performed on the computer to have a special set of instructions designed specifically for that type of task.

   More exotic concepts being proposed deal with a memory system that could retrieve data based on information content. This type of storage is called an associative memory. Another of the more "blue-sky" concepts is the adaptive system. This is a self-organizing machine that could be taught by trial and error to learn to perform a function. This concept is being explored in pattern recognition machines at present.

The advances in the area of software have been at least as dramatic as those in hardware. The earliest programmers were required to communicate with the computer strictly in the language the machine understood (l.e. coded numbers). Through the development of programming languages the programmer can now instruct the computer in a language that is oriented toward the man and the problem he wants solved.

By using executive or operating systems, much of the operation of the computer has been turned over to the machine itself. Again as in the machine components there is a need for increasing the speed and flexibility of man-machine communication. A wide spectrum of flexibility has been achieved in some operating systems currently available with third generation computers. However, many people feel the amount of time required by the computer to provide this flexibility (system overhead) is excessive. Also, some computer manufacturers do not want to spend the time and money necessary to develop a system that may cost as much or more than the development of the computer itself.

A future prospect that may aid in both reducing the cost of producing sophisticated operating systems and make them more efficient is through the use of so-called artificial intelligence techniques. Artificial intelligence is a field which relates to developing systems to perform symbolic algebra manipulations. There are several approaches that make the computer take on human attributes and a semblance of intelligence that is not normally associated with it. There is a great deal of research being done in the area of artificial intelligence, but much remains to be done before the significance of this new field is felt.

One of the early developments in artificial intelligence called PSYCO was designed to have the computer do much of the work in preparing new computer languages and operating systems. This method offers the possibility of reducing the time required to prepare a system by a factor of ten.

The Future of Computing in Texas

It is evident from this brief discussion, that the field of computing has not stabilized. It is progressing dynamically through research by industry, government, and education. No one can predict what the computers of 1980 will be like, other than that they will be faster, more sophisticated, and easier to use.

In order to utilize these computers the institutions of higher learning in Texas must develop a positive program in computing. It has been pointed out repeatedly that we have several institutions in the state with some degree of competence in computing. At the same time, Texas has many institutions with little or no computing capability. Before we can develop a comprehensive program in computing we must first provide a computing capability to all institutions in the state and also further develop those that are currently utilizing computers.

The recommendations contained in this report are designed to foster the development and continuation of coordinated program in computing in Texas higher education. In order for a program of this magnitude in an ever changing field, such as computing, to be developed, however, it is essential for it to be closely observed by an advisory group that is competent to provide continuing policy recommendations and guidance. This insures the ability to adjust the program to be cognizant of unforeseen perturbations of the future. The members of this advisory group should be carefully selected from industry as well as education to provide a view of computing as seen by the user of our institutions' product.

END

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